MODIS DATA STUDY

TEAM PRESENTATION

September 21, 1990

AGENDA

1. Action Items
2. MODIS Level-1 Processing System Design Presentation to the MODIS Science Team
3. Data Flow Definitions at the ICC-PGF Interface
4. Prespecification Descriptions of MODIS Level-1 Processing (FIRST DRAFT; under separate cover).

8/10/90-1 [John Barker]: Specify data requirements for the MCST Support Products (at Level-1A and Level-1B). STATUS: Open.

8/10/90-2 [Al McKay]: Clarify data flow requirements between the ICC and the Level-1 Processing. STATUS: Level-1 processing flows under development; ICC-PGF interface still pending.

MODIS LEVEL-1 PROCESSING SYSTEM DESIGN

PRESENTATION TO THE MODIS SCIENCE TEAM

MODIS SCIENCE DATA SUPPORT TEAM (SDST)

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DRAFT

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NASA/GSFC

DESIGN METHODOLOGY

- Documentation
- Modular Design
- Top-Down Design
- Flexible Design for Easy Modification and Expansion
- EOSDIS Design Standards
- Reviews

DESIGN FEATURES

- Develop Separate MODIS-N and MODIS-T Processing Systems
- Include Multiple Operating Modes
- Compute Earth Locations for Anchor Points Only
- Set Land/Ocean Flags
- Header Record Format Will be Identical for Level-1 and Higher Levels
- Header Record Will Contain Information to Read Data Records
- Develop Validation Software Separate From Production Software
- DEM/DTM not Applied

LEVEL-1A FUNCTIONS

- Receives MODIS Level-0, Platform Ancillary, and Instrument Control Log data
- Assembles and organizes the data sets into scans and orbits
- Constructs and appends scan and orbital headers
- Generates Level-1A metadata
- Delivers Level-1A Data, Metadata, MCST Support Products, and Processing Status/DQA Reports

LEVEL-1B FUNCTIONS

- Receives MODIS Level-1A and Instrument Control Log data
- Navigates on-Earth anchor point and space-look data
- Determines calibration coefficients/model and applies counts-to-radiance conversion to all IFOVs for all bands
- Generates metadata
- Generates scan- and Earth-coordinate browse data
- Sets flags for land/ocean
- Delivers Level-1B Data, Metadata, Browse, MCST Support Products, and Processing Status/DQA Reports

INPUT DATA REQUIREMENTS

- Data Processing
  - Level-0 Data
  - Platform Ancillary Data
  - Instrument Control Log
  - Orbit Number and Orbit Start Time

- Data Validation
  - Ground Control Points
  - GGI, HIRIS
  - Calibration-Related Data (will be supplied by MCST)

PLATFORM ANCILLARY DATA REQUIRED FOR MODIS DATA SYSTEM					
Data Item	Available Resolution	Required Resolution	Range	Bits Required	Bits Proposed[1]
Platform Position	TBS	1 m	±8000 km		
X in GCI				24	32
Y in GCI				24	32
Z in GCI				24	32
Platform Velocity	TBS	0.1 m/sec	±10 km/sec		
X-dot				18	32
Y-dot				18	32
Z-dot				18	32
Platform Attitude	0.05 arcsec	5 arcsec	TBD		
Pitch				18 (if 360° range)	12
Roll				18	12
Yaw				18	12
Times	~1 μsec	0.1 msec	Mission length	64 more than adequate[2]	64
GPS to UTC Time Conversion		As needed to meet 0.1 msec requirement			
Solar array "currents"	TBD	0.1 W/m²	0 to 1600 W/m²	14	8

[1]General Instrument Interface Specification for the EOS Observatory, GE Astro Space [DRAFT], 15 January 1990.

[2]Assuming count in seconds since launch, CCSDS formats may require more bits.

GEOLOCATION ERROR SOURCES FOR MODIS AT NADIR

THREE SIGMA ERROR LIMITS	
CURRENT DESIGN SPECIFICATIONS	
PLATFORM LOCATION UNCERTAINTY	50 METERS/EACH DIRECTION
BASEPLATE ATTITUDE UNCERTAINTY	108 ARCSECONDS/EACH AXIS (370 METERS)
INSTRUMENT LOOK UNCERTAINTY	90 ARCSECONDS/EACH AXIS (308 METERS)
3 σ LOCATION ERROR = 554 METERS	

LEVEL-1A DATA

MODIS instrument data at original resolution, time-ordered, duplicates removed, and reversible to Level-0. Platform ancillary data appended. The sensor data will be in digital counts.

- All available MODIS Level-0 data packets
- Platform ancillary data
- Instrument control log data
- Organized by scans and orbits
- Scan and orbital headers contain information to read the data records, bookkeeping, ephemeris, attitude, data quality, other platform/EOS information, spares, and other TBD parameters
- Fully reversible to Level-0
- Level-1A radiometric data in counts form

LEVEL-1B DATA

Calibrated and navigated MODIS spectral radiances at original resolution (not reversible to Level-0) and other platform and ground ancillary data.

- Missing or transmission-damaged packets are filled
- Only on-Earth MODIS radiometric data calibrated and retained
- Navigation to Earth coordinates applied for sparse array of anchor points
- Not reversible to Level-0 or to Level-1A
- Organized by scans
- Scan and orbital headers contain information to read the data records, bookkeeping, ephemeris, data quality, platform/other EOS information, calibration, spares, and other TBD parameters
- Described in metadata by scenes
- Browse data developed for both Earth-coordinate and scan-coordinate scenes.
- Evaluates instrument performance
- Can generate special/non-standard products on demand

OTHER OUTPUT PRODUCTS

- LEVEL-1A METADATA CONTENTS AND USE
  - Summarized by orbit

- LEVEL-1B METADATA CONTENTS AND USE
  - Summarized by scene

- LEVEL-1B BROWSE CONTENTS AND USE
  - Summarized by scene
  - Both Earth-coordinate and scan-coordinate scenes

OTHER OUTPUT PRODUCTS (CONTINUED)

- MCST SUPPORT PRODUCTS CONTENTS AND USE
  - MCST Support Products will be generated by both Level-1A and -1B processing steps
  - Will be composed of specified on-Earth, internal-calibration, space- and lunar-look, ancillary, and descriptive data and information
  - Product definition may be a combination of both set and varying data requirements

QUESTIONS

The following questions serve to highlight those areas of specific interest to us:

- Does the above scenario for MODIS Level-1 processing meet your requirements?
- What are your requirements for metadata and browse data?
  - Number of bands
  - Scene sizes
  - Should Level-1B browse be georeferenced?
  - Should we have different browse formats for different modes of operation?
  - What descriptive information would you like access to for ordering purposes?

Data Flow Definitions at the ICC-PGF Interface

Instrument Control Log: For each command uplinked to a MODIS instrument, a time code specifying the execution time of the command and a code specifying the command to be executed and any amplifying parameters (angles, etc.) needed to complete the specification of the command. The control log is generated by the ICC and transmitted to the PGF prior to the scheduled execution time of documented commands.

Received Data Anomaly Report: English-language descriptions of anomalous instrument behavior detected during routine data processing at the PGF. Anomaly reports are delivered to operators at the ICC and MCST to provide an alert to an anomalous instrument condition.

PRESPECIFICATION DESCRIPTIONS OF MODIS LEVEL-1 PROCESSING

FIRST DRAFT

September 21, 1990

ROUGH DRAFT AS OF September 21, 1990

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
MODIS Level-1 Processing (1.0)	= Level-1A Processing (1.1) + Level-1B Processing (1.2)
Level-1A Processing (1.1)	= Receive Data (1.1.1) + Assemble Level-1A Data (1.1.2) + Generate Metadata (1.1.3)
Receive Data (1.1.1)	*Verify the identity of received data items (Annotated Level-0 Packets, Platform Ancillary Data, and Instrument Control Log data), generate a Data Receipt Template (one for each instrument scan) containing data entry fields for each Instrument Source Packet or other data item required to complete a scan packet, enter data location pointers in the template for each data item actually received, periodically examine Data Receipt Templates for completeness, and request missing data items or pass acceptable templates to the Assemble Level-1A Data function.* = Verify Identity of Instrument Control Log Data (1.1.1.1) + Control Packet Assembly Process (1.1.1.2) + Receive Annotated Level-0 Data Packets (1.1.1.3) + Receive Platform Ancillary Data (1.1.1.4)
Verify Identity of Instrument Control Log Data (1.1.1.1)	*Examine the header of incoming Instrument Control Log Data to determine that the received data items are actually labeled as Instrument Control Log Data and report results of the examination to the processing supervisor using the Instrument Control Log Receipt Report.* = Examine Control Log Header (1.1.1.1.1) + Generate Control Log Receipt Report (1.1.1.1.2)
Examine Control Log Header (1.1.1.1.1)	Compare header of incoming Instrument Control Log data with appropriate field settings for legitimate Instrument Control Log data.
Generate Control Log Receipt Report (1.1.1.1.2)	On the basis of Verification Findings generated in Examine Control Log Header process, generate an appropriate report to the processing supervisor for use in requesting data retransmission from the ICC, if required.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Control Packet Assembly Process (1.1.1.2)	*Generate one Data Receipt Template for each Level-1A Packet to be output; as receipt of required data items is recorded in templates, periodically examine individual templates to determine completeness of data required to build Level-1A Packets; on the basis of completeness information and data timeliness constraints (Processing Schedule Parameters), accept templates as sufficiently complete and pass templates to Assemble Level-1A Data function or generate missing data descriptors and retain templates for further processing, and as needed, generate Level-0 and Platform Ancillary Data Requests.* = Generate Data Receipt Templates (1.1.1.2.1) + Evaluate Data Receipt Status (1.1.1.2.2) + Generate Data Retrieval Requests (1.1.1.2.3)
Generate Data Receipt Templates (1.1.1.2.1)	On the basis of information in the Instrument Control Log, generate one Data Receipt Template for each instrument scan or other instrument event for which a single Level-1A data packet is desired. The data fields in the templates are to contain pointers to required data and not the actual data itself. Default packets containing appropriate fill values for missing data items are to be provided for each potentially required data item, and templates are to be initially generated with pointers to the fill packets stored in the pointer fields. The default pointers will be overwritten as desired data items are received; missing data items will be automatically filled with the default packets if no proper data item is received.
Evaluate Data Receipt Status (1.1.1.2.2)	Periodically examine the pointer fields in Data Receipt Templates to determine which contain the default pointers (missing data) and which contain pointers for other locations (received data). Evaluate packet completeness and, considering data timeliness constraints (Processing Schedule Parameters), either accept a potential packet (Data Receipt Template) as acceptable for further processing (deliver template as "Completed" Packet Assembly Template) or describe missing data items and pass Missing Data Descriptors to Generate Data Retrieval Request function and hold Data Receipt Template for further processing.
Generate Data Retrieval Requests (1.1.1.2.3)	On the basis of newly-generated Data Receipt Templates recevied directly from the Generate Data Receipt Templates function or Missing Data Descriptors received from the Evaluate Data Receipt Status function, format a data request for needed items in the appropriate query language of the DBMS used by the EOSDIS to provide access to instrument and platform data.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Receive Annotated Level-0 Data Packets (1.1.1.3)	*Verify headers in incoming data to determine that the received data consists of Annotated Level-0 Packets; for each verified packet, determine a template entry location where receipt of that data packet should be recorded; and enter the appropriate Packet Location Pointer in that template location.* = Verify Packet Addresses (1.1.1.3.1) + Identify Template Entry Locations (1.1.1.3.2) + Enter Packet Location Pointers (1.1.1.3.3)
Verify Packet Addresses (1.1.1.3.1)	Compare the settings of specific bit locations in the header of incoming Annotated Level-0 Packets with the required bit settings for legitimate Annotated Level-0 Packets. Generate Level-0 Data Receipt Report for the processing supervisor to use in requesting data retransmission, if required.
Identify Template Entry Locations (1.1.1.3.2)	Interpret header data for Verified Level-0 Packets to determine the appropriate Data Receipt Template location in which to record the receipt of the Level-0 Packet.
Enter Packet Location Pointers (1.1.1.3.3)	For each received Level-0 Packet, enter a storage location pointer for that packet in the appropriate Data Receipt Template field as determined in the Identify Template Entry Locations function.
Receive Platform Ancillary Data (1.1.1.4)	*Verify the header of each Platform Ancillary Data item received to determine that the received data is Platform Ancillary Data; for each verified data item, determine a template entry location where receipt of that data item should be recorded; and enter the appropriate Data Location Pointer in that template location.* = Verify Data Identity Headers (1.1.1.4.1) + Identify Template Entry Locations (1.1.1.4.2) + Enter Packet Location Pointers (1.1.1.4.3)
Verify Data Identity Headers (1.1.1.4.1)	Compare the settings of specific bit locations in the header of incoming Platform Ancillary Data items with the required bit settings for legitimate Platform Ancillary Data. Generate Platform Ancillary Data Receipt Report for the processing supervisor to use in requesting data retransmission, if required.
Identify Template Entry Locations (1.1.1.4.2)	Interpret header data for verified Platform Ancillary Data items to determine the appropriate Data Receipt Template location in which to record the receipt of the data item.
Enter Packet Location Pointers (1.1.1.4.3)	For each received Platform Ancillary Data item, enter a storage location pointer for that item in the appropriate Data Receipt Template field as determined in the Identify Template Entry Locations function.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Assemble Data (1.1.2)	*Construct scans and append header from received Level-0 data.* = Construct Scans (1.1.2.1) + Construct and Append Scan Header (1.1.2.2) + Construct Orbits (1.1.2.3) + Construct Level-1A MCST Support Product (1.1.2.4)
Construct and Append Header (1.1.2.2)	*Platform Ancillary Data and Instrument Control Log are put in the header.* = Synchronize Data (1.1.2.2.1) + Construct Scan Header (1.1.2.2.2) + Append Scan Header (1.1.2.2.3)
Synchronize Data (1.1.2.2.1)	Times of Platform Ancillary Data and Instrument Control Log are found and matched.
Construct Scan Header (1.1.2.2.2)	Platform Ancillary Data and Instrument Control Log are combined in the header.
Append Scan Header (1.1.2.2.3)	Header is appended to scan.
Construct Orbits (1.1.2.3)	*Scans are grouped into orbits and another header is appended.* = Order Scans (1.1.2.3.1) + Construct Orbit Header (1.1.2.3.2) + Append Orbit Header (1.1.2.3.3)
Order Scans (1.1.2.3.1)	Scans are put in the proper order.
Construct Orbit Header (1.1.2.3.2)	Orbit header is constructed using scans with their headers.
Append Orbit Header (1.1.2.3.3)	Orbit header is appended to an orbit of data.
Construct Level-1A MCST Support Product (1.1.2.4)	*Using Level-1A data and MCST Level-1A requirements, the Level-1A MCST support products are produced.* = Extract MCST Requested Level-1A Data (1.1.2.4.1) + Construct MCST Header (1.1.2.4.2) + Append Level-1A MCST Header (1.1.2.4.3)
Extract MCST Requested Level-1A Data (1.1.2.4.1)	Using Level-1A data and MCST Level-1A requirements, the MCST requested Level-1A data are extracted.
Construct MCST Header (1.1.2.4.2)	Using MCST Level-1A requirements, the MCST header is constructed.
Append Level-1A MCST Header (1.1.2.4.3)	MCST header is appended to the MCST requested Level-1A data.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Generate Level-1A Metadata (1.1.3)	= Extract Metadata (1.1.3.1) + Summarize Metadata (1.1.3.2)
Extract Metadata (1.1.3.1)	= Scan Data Receipt Reports (1.1.3.1.1) + Scan Headers (1.1.3.1.2) + Determine Data Processing Parameters (1.1.3.1.3) + Determine Data Completeness (1.1.3.1.4) + Determine Instrument Parameters (1.1.3.1.5)
Scan Data Receipt Reports (1.1.3.1.1)	Peruse data receipt report to seek and output data receipt report information.
Scan Headers (1.1.3.1.2)	Receive Level-1A data, find and output the start/stop time of scan cubes, data processing information, tilt angles, orbit numbers, ephemeris information, and instrument information.
Determine Data Processing Parameters (1.1.3.1.3)	Read data processing parameters which occur during processing at Level-1A. At higher levels, it consists of all data processing parameters associated with the data that were processed by the previous operation.
Determine Data Completeness (1.1.3.1.4)	Check Data Presence Flags for Data Completeness.
Determine Instrument Parameters (1.1.3.1.5)	Extract the instrument information in the headers. = Instrument Operation Mode + Sensor ID + Instrument Configuration History + Platform ID
Summarize Metadata (1.1.3.2)	= Summarize Data Processing Parameters (1.1.3.2.1) + Summarize Scene Completeness/Quality (1.1.3.2.2) + Determine Tilt Angle Ranges (1.1.3.2.3) + Determine Orbit Number Ranges (1.1.3.2.4) + Summarize Instrument Parameters (1.1.3.2.5) + Summarize Ephemeris Information (1.1.3.2.6) + Create Metadata Record (1.1.3.2.7)
Summarize Data Processing Parameters (1.1.3.2.1)	Statistics on data processing parameters which occur during processing at Level-1A. At higher levels, it consists of all data processing parameters associated with the data that were processed by the previous operation. = Processing Level + Algorithm Documentation + Algorithm Version Number + Data Processing Location + Inventory Date + Storage Media

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Summarize Scene Completeness/Quality (1.1.3.2.2)	*States scene quality for scenes formed from processed data.* = TBD parameters
Determine Tilt Angle Ranges (1.1.3.2.3)	Extracts maximum and minimum tilt angles in orbit (or granule) of processed data. = Maximum Tilt Angle + Minimum Tilt Angle
Determine Orbit Number Ranges (1.1.3.2.4)	*Extracts maximum and minimum orbit numbers in processed data.* = Maximum and Minimum Orbit Number Associated With Processed Data at any Level.
Summarize Instrument Parameters (1.1.3.2.5)	Extract the instrument information in the headers. = Instrument Operation Mode + Sensor ID + Instrument Configuration History + Platform ID
Summarize Ephemeris Information (1.1.3.2.6)	Compute statistics concerning ephemeris parameters that were used when processing an orbit of data. = X, Y, Z positions + Platform Velocity from GPS + Other TBD ephemeris parameters
Create Metadata Record (1.1.3.2.7)	Assemble Summarized Data Processing Parameters, Tilt Angle Ranges, Summarized Instrument Parameters, Summarized Ephemeris Parameters, Orbit Number Ranges, and Scene Completeness/Quality.
MODIS Level-1B Processing (1.2)	= Receive Level-1A Data (1.2.1) + Navigate Anchor Points (1.2.2) + Calibrate Data (1.2.3) + Format and Assemble Level-1B Data (1.2.4)
Receive Level-1A Data (1.2.1)	= Verify Data Format (1.2.1.1) + Evaluate Instrument Performance (1.2.1.2)
Verify Data Format (1.2.1.1)	= Select Format Template (1.2.1.1.1) + Compare Received Packets with Templates (1.2.1.1.2)
Select Format Template (1.2.1.1.1)	Given status bit and word settings in the instrument control log indicating the mode of operation of the MODIS instrument, select an expected data format template from a file of possible standard format templates.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Compare Received Packets with Templates (1.2.1.1.2)	Compare the contents of Level-1A data packets against the standard format template. Forward each scan packet that passes the format check. Generate a format anomaly report for all scan packets that are rejected due to format inconsistencies. (Do we want to reject inconsistent Level-1B data at this point?)
Evaluate Instrument Performance (1.2.1.2)	= Verify Instrument Status Bit Settings (1.2.1.2.1) + Verify Instrument Engineering Parameter Ranges (1.2.1.2.2) + Other Instrument Performance Tests (1.2.1.2.3)
Verify Instrument Status Bit Settings (1.2.1.2.1)	Given format-checked MODIS scan packets at Level-1A, perform a verification of instrument status bit settings through a comparison to entries in the instrument control log. As discrepancies are noted, generate status reports describing the anomalies.
Verify Instrument Engineering Parameter Ranges (1.2.1.2.2)	Verify the MODIS instrument performance by a series of quality control tests on the Level-1A scan packet contents specific to the information contained in the instrument control log. Create a report summarizing the set of envelope tests.
Other Instrument Performance Tests (1.2.1.2.3)	Given the Level-1A scan packets and the instrument control log data, perform any other instrument performance verifications possible to fulfill "in-line" quality control requirements. Report on the other instrument test results.
Navigate Anchor Points (1.2.2)	*Determine Earth location and auxiliary angles for anchor points.* = Unpack Navigation Data (1.2.2.1) + Select Anchor Points (1.2.2.2) + Interpolate Platform Ephemeris (1.2.2.3) + Line of Sight Determination (1.2.2.4) + Compute Solar and Lunar Geometry at Platform (1.2.2.5) + Earth Locate Anchor Points (1.2.2.6) + Compute Solar and Lunar Angles (1.2.2.7)
Unpack Navigation Data (1.2.2.1)	*Find navigation data in scan headers and ancillary data.* = Unpack Time-Tags and Data Flags (1.2.2.1.1) + Determine Scan Times (1.2.2.1.2) + Match Ancillary Data (1.2.2.1.3) + Convert Mirror Positions (1.2.2.1.4)
Unpack Time-Tags and Data Flags (1.2.2.1.1)	From the scan headers and the ancillary data headers, pick off the times and flags for data presence and quality.
Determine Scan Times (1.2.2.1.2)	Find the start and end times of the scans or partial scans which are present in the data to be processed.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Match Ancillary Data (1.2.2.1.3)	Find the data within the ancillary data set which corresponds to the scan, with 2 (TBD) sets of values to each side. For a 1 second scan, 14 sets of ancillary data (at a 10 Hz rate) are required, more for MODIS-T.
Convert Mirror Positions (1.2.2.1.4)	Change the mirror positions in raw counts into scan angles and associated times.
Select Anchor Points (1.2.2.2)	*Determine appropriate anchor points based on data presence and quality.* = Compare Data Present with Default Anchor Point Positions (1.2.2.2.1) + Choose Alternate Anchor Points if Required (1.2.2.2.2) + Interpolate Across Missing Data if Required (1.2.2.2.3)
Compare Data Present with Default Anchor Point Positions (1.2.2.2.1)	Compare the default anchor point positions against the data flags to find the flags for the anchor point positions.
Choose Alternate Anchor Points if Required (1.2.2.2.2)	Select alternate anchor points or omit them if large portions of data are unusable.
Interpolate Across Missing Data if Required (1.2.2.2.3)	Find anchor point information by interpolation if small data gaps are present at anchor point positions.
Interpolate Platform Ephemeris (1.2.2.3)	*Platform ephemeris values are required at anchor point times.* = Identify Ephemeris Values Spanning Anchor Point Time (1.2.2.3.1) + Interpolate Position and Velocity (1.2.2.3.2) + Interpolate Attitude (1.2.2.3.3) + Combine Interpolated Data (1.2.2.3.4)
Identify Ephemeris Values Spanning Anchor Point Time (1.2.2.3.1)	From the set of ephemeris values for the scan, find the 2 (TBD) values bracketing the anchor point time.
Interpolate Position and Velocity (1.2.2.3.2)	Find the position and velocity at the anchor point time.
Interpolate Attitude (1.2.2.3.3)	Find the attitude at the anchor point time.
Combine Interpolated Data (1.2.2.3.4)	Write the position, velocity, and attitude into a set for processing of the anchor point.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Line of Sight Determination (1.2.2.4)	*Find orientation of MODIS-look vector.* = Apply Scan Angle Biases and Timing Corrections (1.2.2.4.1) + Calculate Line of Sight Alignment to Sensor Baseplate (1.2.2.4.2) + Apply Mounting and Flexure Biases (1.2.2.4.3) + Rotate Vector by Platform Attitude (1.2.2.4.4) + Convert to Inertial Frame Using Platform Position (1.2.2.4.5)
Apply Scan Angle Biases and Timing Corrections (1.2.2.4.1)	Adjust mirror positions by known biases and correct any timing offsets.
Calculate Line of Sight Alignment to Sensor Baseplate (1.2.2.4.2)	Find line of sight vector from tilt and scan angles.
Apply Mounting and Flexure Biases (1.2.2.4.3)	Rotate line of sight vector to platform frame.
Rotate Vector by Platform Attitude (1.2.2.4.4)	Rotate line of sight vector to orbital frame.
Convert to Inertial Frame Using Platform Position (1.2.2.4.5)	Rotate line of sight vector to geocentric inertial frame.
Compute Solar and Lunar Geometry at Platform (1.2.2.5)	*Sun and Moon positions must be known for the following calculations.* = Compute Geocentric Solar and Lunar Positions (1.2.2.5.1) + Correct Platform Offset from Earth Center (1.2.2.5.2)
Compute Geocentric Solar and Lunar Positions (1.2.2.5.1)	The primary quantity to compute is the Earth-sun distance in astronomical units, which will be used by many other algorithms. Solar right ascension and declination must also be computed. (It is important that all algorithms use the same values for self-consistency. Since the correct computation of these numbers are computationally rather intensive, it is probably best to calculate them perhaps once per orbit to be used for that orbit.) Compute the following lunar geometry parameters: (1) Time and date of full moon or the phase of the moon, 2) time and scan angle when moon is viewed by MODIS, 3) Earth-moon distance at this time, and 4) libration of the moon. (Lunar geometry is required for calibration studies. These geometric quantities will be used to calculate the albedo of the moon or model the albedo distribution across the disk of the moon, and used to calculate lunar radiance values at the resolution of the MODIS instruments.)
Correct Platform Offset from Earth Center (1.2.2.5.2)	Allow for orbital parallax effect.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Earth Locate Anchor Points (1.2.2.6)	*Perform geometrical calculations to find the latitude and longitude of the pixel.* = Solve for Intersection of Vector and Earth (1.2.2.6.1) + Derive Geocentric Latitude of Pixel (1.2.2.6.2) + Convert Geodetic Latitude (1.2.2.6.3) + Find Earth Position at Reference Time (1.2.2.6.4) + Derive Longitude of Pixel (1.2.2.6.5) + Assemble Navigation Results (1.2.2.6.6)
Solve for Intersection of Vector and Earth (1.2.2.6.1)	Algebraically solve for the intersection of the line of sight vector with the ellipsoid modeling the Earth.
Derive Geocentric Latitude of Pixel (1.2.2.6.2)	Calculate arctan $[z/(x^2 + y^2)^{1/2}]$.
Convert Geodetic Latitude (1.2.2.6.3)	Convert geocentric latitude to Earth latitude by known formulas.
Find Earth Position at Reference Time (1.2.2.6.4)	Find the position of the Earth with respect to inertial coordinates, allowing for conversion from dynamical time to universal time.
Derive Longitude of Pixel (1.2.2.6.5)	Find the longitude from the Earth position and x and y.
Assemble Navigation Results (1.2.2.6.6)	Write latitude and longitude to header and issue DQA report.
Compute Solar and Lunar Angles (1.2.2.7)	*Angles between the MODIS line of sight vector and Sun and Moon at platform and at the pixel will be required.* = Rotate Line of Sight and Sun Vectors to Topocentric Coordinates (1.2.2.7.1) + Extract Spacecraft Solar Zenith and Azimuth Angles (1.2.2.7.2) + Calculate Separation Between Line of Sight, Sun, and Moon (1.2.2.7.3) + Append Auxiliary Angle Data (1.2.2.7.4)
Rotate Line of Sight and Sun Vectors to Topocentric Coordinates (1.2.2.7.1)	Rotate the two vectors by the longitude and latitude angles to find the viewpoints to the pixel.
Extract Spacecraft Solar Zenith and Azimuth Angles (1.2.2.7.2)	Apply inverse trigonometric functions to the vector components.
Calculate Separation Between Line of Sight, Sun, and Moon (1.2.2.7.3)	Take dot products between these vectors at the platform.
Append Auxiliary Angle Data (1.2.2.7.4)	Write results of calculations to header and to DQA reports.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Format and Assemble Level-1B Data (1.2.4)	= Assemble Level-1B Data (1.2.4.1) + Define Scenes (1.2.4.2) + Generate Level-1B Metadata (1.2.4.3) + Generate Browse Data (1.2.4.4)
Assemble Level-1B Data (1.2.4.1)	= Combine DQA and Operations Reports (1.2.4.1.1) + Construct Headers (1.2.4.1.2) + Merge Level-1B Data (1.2.4.1.3)
Combine DQA and Operations Reports (1.2.4.1.1)	Combine data quality assurance information relating to navigation and calibration processes with available information on the instrument operation during a given scan to generate joint Level-1B quality assurance reports.
Construct Headers (1.2.4.1.2)	Given the Level-1B quality assurance reports, do the following: (1) extract descriptive data, particularly navigation related, that will support the definition of scenes and (2) generate a descriptive header for the scan of data.
Merge Level-1B Data (1.2.4.1.3)	Given the descriptive header, navigation information, and an entire set of calibrated radiances (on-Earth, off-Earth, and internal calibration) do the following: (1) merge the three input data sets into a Level-1B scan cube; (2) extract support product information for the MCST; and (3) extract on-Earth data only for creation of the MODIS Level-1B product.
Define Scenes (1.2.4.2)	= Construct Scenes (1.2.4.2.1) + Extract Header (1.2.4.2.2) + Summarize Header Data (1.2.4.2.3) + Append Header (1.2.4.2.4)
Construct Scenes (1.2.4.2.1)	Group a scan cube according to the scene specifications without creating a summarizing header (each scan cube contains its own header).
Extract Header (1.2.4.2.2)	Given a group of scan cubes that correspond to a specified scene, extract the headers from each scan cube.
Summarize Header Data (1.2.4.2.3)	Given a set of headers for a set of scan cubes, summarize the information for the scene to generate a summary header.
Append Header (1.2.4.2.4)	Append the scene summary header to the scene of radiance to create a labelled Level-1B scene.
Generate Level-1B Metadata (1.2.4.3)	= Extract Level-1B Metadata (1.2.4.3.1) + Summarize Level-1B Metadata (1.2.4.3.2)
Extract Level-1B Metadata (1.2.4.3.1)	Use specified boundaries to extract descriptive metadata information from a larger Level-1B data set.

MODIS LEVEL-1 PROCESSING SYSTEM PRIMITIVE PROCESS FUNCTIONAL SPECIFICATIONS	
PROCESS	**SPECIFICATION**
Summarize Level-1B Metadata (1.2.4.3.2)	Given extracted Level-1B information, perform value-added summaries to yield Level-1B metadata.
Generate Browse Data (1.2.4.4)	= Spatial Subsampling, Spectral Subsetting, Word-length Truncation (1.2.4.4.1) + Earth-Mapping (1.2.4.4.2) + Statistical Analysis (1.2.4.4.3) + Extract Browse Descriptive Data (1.2.4.4.4) + Create Browse Data (1.2.4.4.5)
Spatial Subsampling, Spectral Subsetting, Word-length Truncation (1.2.4.4.1)	Spatial Sub-Sampling: reduction in spatial resolution by selection of a subset of the pixels in space; Spectral Sub-Setting: reduction in spectral resolution by selection of a subset of the wavelengths; Word-Length Truncation: reduction in dynamic resolution by creating reduced byte words from the 16-bit words of the actual data.
Earth-Mapping (1.2.4.4.2)	Application of map projection algorithms to data to produce Earth-located (latitude, longitude) data organized by the selection map projection.
Statistical Analysis (1.2.4.4.3)	Application of algorithms to create histograms and scatterplots.
Extract Browse Descriptive Data (1.2.4.4.4)	Extract information from the Level-1B metadata that is required for browse; examples include tilt angles, times, algorithm and sensor identification, and navigation of scene corners.
Create Browse Data (1.2.4.4.5)	Overlay appropriate vectors from the coastline file onto mapped Level-1B scenes; take mapped and scan coordinate Level-1B scenes and combine statistical information (e.g., histograms/scatterplots) to generate browse records for Level-1B.